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JUL 77 S I PANOV, Y I YUSHIN

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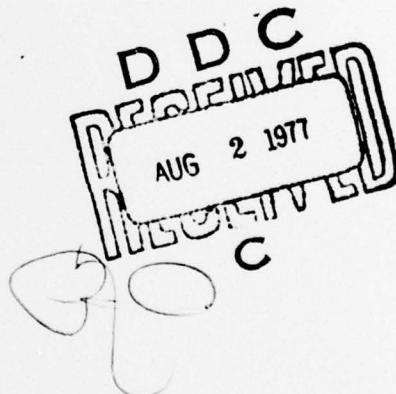
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METHOD FOR DETERMINING DEFORMABILITY
OF PERMAFROST FOUNDATIONS
BEFORE AND AFTER THAWING

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S.I. Panov and Yu.I. Yushin



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for permafrost foundations using the "hot plate" technique is proposed as well as a method for data reduction.

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METHOD FOR DETERMINING DEFORMABILITY OF PERMAFROST FOUNDATIONS BEFORE AND AFTER THAWING

[Article by S. I. Panov, candidate of engineering sciences and Yu. I. Yushin, engineer; All-Union Scientific Research Institute of Hydrotechnology [VNIIG]: "Method for Determining the Deformability of Permafrost Foundations Before and After Thawing"]

[Text] Reliable and economic planning for large-scale energy, hydrotechnical and industrial civil engineering installations in permafrost regions is not possible without efficient forecasting of changes in deformation and in the supporting capacity of frozen foundations after full or partial thawing.

Presently the most widespread method for forecasting deformation changes of the frozen foundations during thawing is testing the strata under natural conditions with the aid of the so-called "hot plate" technique. The difference of this testing method from those usually used is that the foundation under the test die prior to or during the test process thaws with the help of various kinds of devices at any depth. The deformations of the foundation under the load attached to the test die are measured and used to determine the deformation characteristics of the foundation strata. At the same time the values of the displacements of the die and surface of the massif foundation around it are placed into certain theoretical functions permitting determination of the deformation ratio (E_{AE}) and the modulus of elasticity (E_{np}) of the medium of the foundation's die.

As a rule the functions that are used are derived from solution of problems on the stresses and deformations of a homogeneous elastic and compact half space (or half-plane) loaded with any stress distributed throughout the area of the free surface.

It is quite natural that the use of similar solutions in the case of a piecewise homogeneous half-space (of the most complete simulated foundation massifs with a localized thaw zone) might lead to a significant error in determining the parameters of the medium's deformability. The value of this error will probably depend on the correlation of measurements of the test die and the thaw zone, as well as on the degree of change in the ratio of strata deformation during thawing.

With the purpose of obtaining more complete computational and theoretical bases for interpreting the results of similar researches, a problem was solved on the stresses and deformations of an elastic half-plane with a piecewise homogeneous inclusion of an arbitrary configuration loaded on a certain section of the rectilinear contour with a stress transmitted by a die of finite rigidity. The calculations chart for this problem is shown in illustration no 1.

The problem was solved numerically on an M-222 electronic digital computer using the method of finite elements [1] under the following circumstances:

- a. the width of the die (b) -- a constant value;
- b. the width of the foundation thaw zone (b_{OT}) -- a constant equal to $1.5b$;
- c. the depth of the thaw zone (h_{OT}), a variable taking on any value at an interval of 0 to $4b$;
- d) the strata deformation ratio in the thaw zone (E_{OT}) might be less than the strata deformation ratio beyond the thaw zone (E_{mep3}), whereupon the ratio E_{OT}/E_{mep3} takes on a value in the interval from 1 to 0.025;
- e. Poisson's ratio for strata in frozen and thawed conditions -- a constant value equal to 0.25;
- f. the deformation ratio for the die material takes on an equal strata deformation ratio beyond the limits of the thaw zone.

Chart

ILLUSTRATION NO 1. Constraint Diagram $\frac{W_{OT}}{W_{mep3}} = \mathcal{J} \left(\frac{E_{OT}}{E_{mep3}} \right)$

1. Coefficient $K_1 = \frac{E_{OT}}{E_{mep3}}$

2. h_{OT} in segments from b_{OT}

3. Computation diagram

The solution results are in the form of dimensionless constraint diagrams for the corelationships of vertical displacements before and after thawing (W_{OT}/W_{mep3}) and the strata deformation ratio within and beyond the limits of the thaw zone under distinct values h_{OT} are cited in illustration no 1.

The computed solution allows for proposing the methodology for carrying out deformability tests for frozen and piecewise thawed foundations, as well as the methodology for processing the results derived taking into account the possible nonhomogeneity of the massif's deformability.

The essence of the proposed methodology is included in the following:

1. The foundation being tested in a natural (frozen) condition is loaded with a die to which some load with intensity q is attached. At the same time a displacement of the surface of the foundation massif is affixed under the center of the die (E_{mep3}^{odw}). In preparing the die for this purpose a special open housing must be provided.
2. Removal of the die is done with a probe of the corresponding displacement of the processed surface for the purpose of isolating the elastic and residual portion of the foundation's deformations (w_{mep3}^{ct}).
3. After removal of the die, thawing of the foundation takes place at a certain depth h_{ct} selected in accordance with which layer for capacity one is interested in researching.
4. Once again, as in the first cycle of the test, loading and subsequent removal of the die is done. Simultaneously, the general and residual vertical massif surface displacements under the center of the die are secured -- w_{ct}^{odw} and w_{ct}^{ct} .
5. By assuming that the completely frozen foundation during short-term loading with a moderately dimensioned load conducts itself as an isotropic elastic massif, the strata deformation ratio is determined in a frozen state E_{mep3} . At the same time known solutions for the theory of elasticity as well as values q and w_{mep3} are used.

Chart

ILLUSTRATION NO 2 Constraint plots $\frac{w_0}{w_m} = \zeta \left(\frac{E_0}{E_m} \right)$ when $mep3 \approx h_c = b$

1. Relationship of ratios E_0/E_m

2. $m = \frac{\zeta}{b}$ when $h_0 = b$

3. Computation diagram

6. With the known relationship w_{ct}/w_{mep3} and the corresponding depth of thawing h_{ct} , the value of the coefficient k_1 is determined according to the plots in illustration no 1.

7. The strata deformation ratio in the thaw zone is determined in the following manner:

$$E_{\sigma_1} = K_1 E_{m \times p_3}$$

8. The residual and elastic portions of the general displacements allow, using analogous methodology, for determination of the parameters of stratal subsistence during thawing and of the statistical modulus of elasticity for subsistence.

The tests expeditiously conducted during a subsequent increase in the depth of the thaw zone allow for determination not only of an average for the entire thaw zone depth value for the parameters of stratal deformability, but for the nonhomogeneity of its deformability according to depth.

When using the plots in illustration no 1 one must absolutely bear in mind that they are derived in the instance of a plane problem. While loading the half-space with the die a spatial problem takes place. The error of transferring the results of a two-dimensional problem into a three-dimensional case we attempt to evaluate in the following manner.

Let us affix a load with the intensity q to the surface of a two-layer foundation with the help of a die having the relationship of sides $m = 1/b$. The upper structural layer of the foundation has the capacity h_o and the deformation ration E_o . The strata foundation's residual portion contains the deformation ratio E_m .

The settling of the die, accordingly [2], can be determined by the laminar summation according to the following relationship:

$$W = \sum_{i=1}^n q_i h_i \frac{3}{E_i}$$

Where n is the number of layers on which the foundation has been conditionally broken within the limits of the compressible stratum; q_i is the normal vertical pressure transmitted by the die in the middle layers; h_i is the thickness of the i layer; E_i is the strata deformation ratio in it; β is the adjustment coefficient.

By giving distinct values to q , E_o , E_m , m and h_o and using the table of distribution q_i according to depth, we determine to values W corresponding to each of the calculated cases.

If the sagging of the die during $E_o = E_m$ is designated by W_m all the residual values $E_o \neq E_m$ by W_c , then the curved connections $W_c/W_m = f(E_o/E_m, h_o, m)$ plotted for a two-layer foundation will be analogous to the curves of illustration no 1 plotted for a half-plane with a piecewise homogeneous inclusion.

Illustration no 2 shows such curves corresponding to one value $h_0 = b$ and several values m .

When $m \geq 10$ in the vertical cross section passing through the middle of the long sides of the die, the distribution of the stresses and deformations practically coincide with the incident of plane deformation. When taking readings we correlate the curves $\omega_c/\omega_m = f(E_c/E_m)$ plotted for the distinct values m with the curve corresponding to $m \geq 10$.

Correlation allows for evaluating the use error of results from the two-dimensional problem for dies with dissimilar relationships of the sides. As can be seen from the chart in illustration no 3, in the instance of a two-layer foundation the use error for solving the plane problem, while interpreting the results of the tests carried out with the aid of dies with a relationship of sides where $m = 1$. At the same time the value of the deformation ratio, determined according to test results, can prove to be overstated by 28 \pm 30 percent (when $E_c/E_m \leq 0.05$). Certainly this error is inadmissibly great. However, from the chart being examined it follows that with a sides relationship where $m = 2$, the maximum error value decreases to 12-13 percent, and where $m = 3$, up to 6-6.5 percent. Such an error conforms with the value for determining displacements of reference points of the foundation while conducting the tests under field conditions.

If prior to carrying out an exact solution to the spatial problem we consider that the difficulties in transferring the solutions for a two-dimensional problem into a three-dimensional case for a two-layer space and for space with a localized piecewise homogeneous inclusion correlated according to value, then the function (1) for determining the deformation ratio can be presented in this form:

$$E_{ot} = K_1 K_2 E_{me} \rho_3 \cdot \eta \quad (11b)$$

where k_1 is the correction factor determined according to the charts of illustration no 1; k_2 is the shape coefficient of the die equal to:

$$\begin{aligned} 0.77 & \text{ -- when } m = 1 \\ 0.89 & \text{ -- when } m = 2 \\ 0.94 & \text{ -- when } m = 3 \\ 1.00 & \text{ -- when } m = 10 \end{aligned}$$

In conclusion it is worth noting that the methodology presented for testing the deformative properties of frozen foundations calls for determination of values only for the deformation ratio and the modulus of elasticity. This is dependent upon the theoretical functions used for processing the results of the tests conducted using plane dies [2]. They include Poisson's ratio only in the form of a co-factor $(1 - v^2)$. What has been plotted does not allow for determining the value of Poisson's ratio with a loading of a

homogeneous or piecewise homogeneous half-space with a vertical die load. In addition, this offers the possibility having taken $\nu = 0.25$ to determine the deformation ratio without a large error (4.5-6 percent), since the real values of Poisson's ratio for frozen and thawed mountainous strata are to be found within the limits of 0.15-0.35.

When it becomes necessary to precisely determine Poisson's ratio for frozen or thawed strata more complex charts for foundation load must be used [4].

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